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Sand burrowing mayflies of the family Behningiidae (Ephemeroptera) from South Korea

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Abstract
New distributional record of little-known Behningiidae is presented from South Korea for *Behningia tshernovae* Edmunds & Traver, 1959. South Korea represents the first report of the species outside of the Russian Far East. We provide the photos of *B. tshernovae* nymphs as well as the male and female for diagnosis and confirm the previously known relation between the larva and adult.

Keywords
Distribution, new record, *Behningia.*

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Introduction

Behningiidae are small mayfly family consisting of only three genera and six species worldwide (Bauernfeind and Soldán 2012). They are characterized by their unique morphology as sand dwellers (Fig. 1) and little is known regarding their biology and ecology. Among them, the genus *Behningia* Lestage, 1929 currently comprises three species, occurring in East and West Palaearctic, and Oriental regions, respectively (Bauernfeind and Soldán 2012).

Within *Behningia* Lestage, 1929, *Behningia lestagei* Motas & Bacesco, 1937 was described from a single female larva and the validity of the species has been discussed by various authors (Bauernfeind and Soldán 2012). Hubbard (1994) and McCafferty & Jacobus (2006) recognized the species as distinct from *B. ulmeri* Lestage, 1929, but Bauernfeind and Soldán (2012) considered the species as a junior subjective synonym of *B. ulmeri* Lestage, 1929.

Behningia tshernovae Edmunds & Traver, 1959 is currently known only from the Russian Far East (Edmunds and Traver 1959; Hubbard 1994; Tiunova 1997, 2009, 2012; Bauernfeind and Soldán 2012). According to McCafferty and Jacobus (2006), *B. tshernovae* nymph sensu Edmunds and Traver (1959) actually referred to *B. ulmeri* Lestage, 1929 (as *B. lestagei* Motas & Bacesco, 1937) and the nymph of *B. tshernovae* is unknown or questionable. We examined several Korean *B. tshernovae* nymphs and male imagoes and female subimagoes grown from the nymphs and confirmed that the diagnostic characters and the key to species given by previous authors (Tshernova 1964; Hubbard 1994; Bauernfeind and Soldán 2012) are correct.

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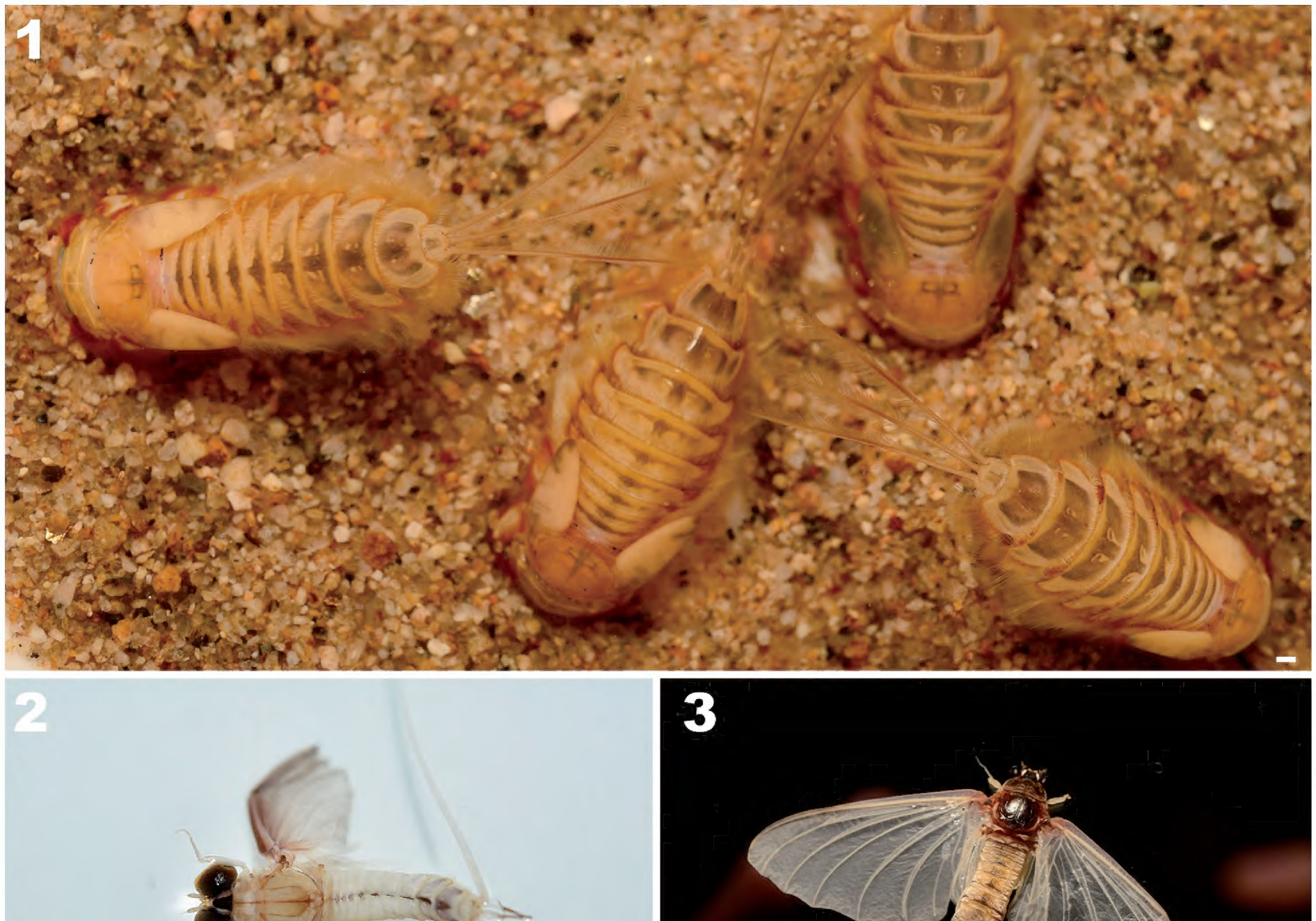

Figures 1–5. *Behningia tshernovae* Endmunds & Traver, 1959 from South Korea. **1.** Live habitus of nymphs, 180331HR-1. **2.** Male imago, dorsal view, 180331SW-1. **3.** Female subimago, dark morph, dorsal view, 180331SW-1. **4.** Female subimago, pale morph, ventral view, 180331SW-1. **5.** Male genitalia, ventral view, 180331SW-1. Scale bars = 1 mm.

Here we report the first distributional record of Behningiidae in South Korea and confirm larval-adult association.

Methods

The examined specimens are deposited in the College of Agriculture and Life Science, Seoul National University, Seoul, Korea (SNU). We follow the *Behningia* species concept by Bauernfeind and Soldán (2012). Photographs are taken with digital cameras (Nikon D7000 and D810 with Nikon AF Micro Nikkor 60mm f/2.8D Lens, Nikon, Japan and Olympus Tough TG-4, Olympus, Japan. The substrate of sand stream, collection site of *B. tshernovae*, consisting of find sand having a grain size of 0.06–1.00 mm.

Mayfly nymphs were reared and hatching had been demonstrated in the laboratory at room temperature with no light period control. The rearing method is detailed as follows: A fish tank was utilized and the tank size was

260 × 180 × 180 mm. The sand from habitat was collected and used for rearing. The water from the habitat was used and filtered every two weeks with an oxygen bubble generator. The tank was exposed to natural light which was regulated with shade cloth to maintain light intensity. Three to six individuals were reared together in a tank.

Results

Behningiidae Motas & Bacesco, 1937
Behningia Lestage, 1929

***Behningia tshernovae* Edmunds & Traver, 1959**
Figures 1–5

Material examined. South Korea • Gyeongsangnam-do, Hapcheon-gun, Cheongdeok-myeon, Gahyeon-ri, Cheongdeokgyo, 35°34′19″N, 128°20′36″E, 31 Mar. 2018, 4 nymphs, H.R. Park leg. (SNU 180331HR-1). • Gyeongsangnam-do, Hapcheon-gun, Cheongdeok-myeon, Gahyeon-ri, Cheongdeokgyo, 35°34′19″N, 128°20′36″E, 31 Mar. 2018, 4 nymphs, S.W. Lee leg. (SNU 180331SW-1). • Gyeongsangnam-do, Hapcheon-gun, Cheongdeok-myeon, Gahyeon-ri, Cheongdeokgyo, 35°34′19″N, 128°20′36″E, 31 Mar. 2018, emerged 25 July 2018, 1 female subimago, 1 exuvia, H.R. Park leg. (SNU 180725HR-1). • Gyeongsangnam-do, Hapcheon-gun, Cheongdeok-myeon, Gahyeon-ri, Cheongdeokgyo, 35°34′19″N, 128°20′36″E, 31 Mar. 2018, emerged 15 June 2018, 2 exuviae, H.R. Park leg. (SNU 180331HR-1). • Gyeongsangnam-do, Hapcheon-gun, Cheongdeok-myeon, Gahyeon-ri, Cheongdeokgyo, 35°34′19″N, 128°20′36″E, 25 June 2018, 3 exuviae, H.R. Park leg. (SNU 180331HR-1). • Gyeongsangnam-do, Hapcheon-gun, Cheongdeok-myeon, Gahyeon-ri, Cheongdeokgyo, 35°34′19″N, 128°20′36″E, emerged 29 July 2018, 1 female subimago, 1 exuvia, H.R. Park leg. (SNU, 180729HR-1).

Distribution. Far East Russia (Edmunds and Traver 1959; Hubbard 1994; Tiunova 1997, 2009, 2012; Bauernfeind and Soldán 2012; Kluge 2019), South Korea (Gyeongsangnam-do) (new record).

Identification. Specific papers were used for species identification using published keys (Tshernova 1964; Hubbard 1994; Bauernfeind and Soldán 2012). There are only three extant species in *Behningia* worldwide, and, among them, *Behningia baei* McCafferty & Jacobus, 2006 is distinct in morphology (the trochanter of middle legs is considerably longer than the coxa) and distribution (Oriental region). The main characteristic differentiating larvae of the remaining two Palaearctic species are the shape of labial palps and the arrangement of bristles on labial palps (Hubbard 1994; Bauernfeind and Soldán 2012). In *B. tshernovae*, the apical segment of labial palp is irregularly but evenly covered with bristles of distinctly different length and size, stout bristles are scattered on outer margin (the segment with dense, long and fine bristles on outer marginal surface, bristles arranged in well distinguished longitudinal rows in *B. ulmeri*). Additionally, adult characters such as the shape of antennal pedicle, compound eyes are also useful (the antennal pedicle longer than ½ of scape in *B. tshernovae*, 4–5 times shorter than scape in *B. ulmeri*; the compound eyes oval in *B. tshernovae*, spherical in *B. ulmeri*) (Bauernfeind and Soldán 2012).

Discussion

The examination of relevant material obtained by collecting and rearing revealed unambiguous association between nymph and adult, and thus we can confirm the taxonomy of *Behningia tshernovae* given by Edmunds and Traver (1959) and Tshernova (1964). We confirmed that females show two colour morphs (dark and pale) (Figs 3, 4). The habitat of *B. tshernovae* Edmunds & Traver, 1959 is restricted to finer sand stream (Fig. 6) and, as well as, high quality water is needed for their survival. For decades, South Korean streams and rivers have suffered from waterfront developments and dam constructions. Especially the sandy habitats have gradually decreased in South Korea, which threatened the survival of sand dwelling organisms, and several species, such as *Macromia daimoji* Okumura, 1949, *Gobiobotia nakdongensis* Mori, 1935, and *Microphysogobio koreensis* Mori, 1935, are now considered endangered. *Behningia tshernovae* is also known to live in a very restricted area, and for the sustainability of the species, the conservation of its habitat and preservation of water quality are urgently required.

Figure 6. Habitat of *Behningia tshernovae*.

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Authors' Contribution

HRP, SWL, and GC wrote the text; HRP and SWL collected material and provided photographs; GC identified the species, and made the illustration.

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